



## ‘Better living through sensory’; how sensory cues moderate our eating behaviour, food intake and health

Ciarán G. Forde\*

*Sensory Science and Eating Behaviour Chair group, Division of Human Nutrition, Wageningen University, the Netherlands*

### ARTICLE INFO

#### Keywords:

Sensory-nutrition  
Eating rate  
Food texture  
Energy intake  
Children  
Ultra-processed food

### ABSTRACT

Food choice and energy intake are influenced more by the sensory and cognitive aspects of eating than the nutritive properties of the food being consumed, yet chronic-disease and ill-health result from prolonged exposure to diets of poor nutrient quality. The role of dietary patterns in diet-related chronic conditions is undisputed, yet this is of little value if we cannot change unhealthy food patterns. Sensory properties are shaping ‘what’, ‘how much’ and ‘why’ we eat, and influence the learning that drives the dietary-patterns that influence health. Not all calories are equal, and food-texture, taste and aroma direct choice, inform eating behaviours and directly influence meal size. Consuming energy dense foods at a faster eating rate promotes higher intakes and poor-health. Sensory is uniquely positioned at the cross-roads of food science, nutrition and consumer behaviour to influence the transition to healthier and more sustainable diets. Addressing the serious public-health challenges posed by the modern food-environment will require changes in dietary-patterns and eating behaviours that are easy for consumers to adopt. Using sensory properties makes it possible to promote healthier eating behaviours and can inform the development of successful dietary strategies that keep food enjoyment and satisfaction at the heart of healthy eating.

Video to this article can be found online at <https://doi.org/10.1016/j.sctalk.2024.100349>.

### CRedit authorship contribution statement

**Ciaran G. Forde:** Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Supervision, Writing – original draft, Writing – review & editing.

### Data availability

Data will be made available on request.

### Acknowledgments

**Funding:** This work was supported by the Dutch Top-Consortium for Knowledge and Innovation Agri & Food (TKI-Agri-food) Projects Restructure; (TKI 22.150) and Meta-Pro. (LWV22098); the Metabolic Impact of Food Processing (Meta-Pro) The ‘Restructure’ project is a public-private partnership on precompetitive research on the influence of food texture and eating rate on energy intake. For more information go to <https://restructureproject.org/>. Meta-Pro is a public private partnership on

precompetitive research to understand the impact of food processing on food matrix and metabolic responses.

### Declaration of interests

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Ciaran G. Forde has received ongoing research financial support from the TKI Top Sector Agri-Food program (the Netherlands). Ciaran G. Forde reports both paid and non-paid relationships with Kerry Taste and Nutrition, Pepsico, United States Department of Agriculture, General Mills, GB Foods, ILSI-SEA, Institute for Food Technologists, Mondelez, Ajinomoto, British Nutrition Society World Sugar Research Organization, and the Northern Irish Dairy Council, that includes consulting/advisory and travel reimbursement.

### Further reading

- [1] C.G. Forde, From perception to ingestion; the role of sensory properties in energy selection, eating behaviour and food intake, *Food Qual. Prefer.* 66 (2018) 171–177, <https://doi.org/10.1016/j.foodqual.2018.01.010>.
- [2] K. McCrickerd, C.G. Forde, Sensory influences on food intake control: moving beyond palatability, *Obes. Rev.* 17 (2016) 18–29, <https://doi.org/10.1111/obr.12340>.

\* Corresponding author.

E-mail address: [Ciaran.forde@wur.nl](mailto:Ciaran.forde@wur.nl).

- [3] C.G. Forde, K. De Graaf, Influence of sensory properties in moderating eating behaviors and food intake, *Front. Nutr.* 9 (2022) p.841444.
- [4] L.B. Sørensen, P. Møller, A. Flint, M. Martens, A. Raben, Effect of sensory perception of foods on appetite and food intake: a review of studies on humans, *Int. J. Obes.* 27 (10) (2003) 1152–1166, <https://www.frontiersin.org/articles/10.3389/fnut.2022.841444/abstract>.
- [5] E. Robinson, E. Almorin-Roig, F. Rutter, C.G. Forde, C. de Graaf, S. Jebb, A systematic review and meta-analysis examining the effect of eating rate on energy consumption and hunger, *Am. J. Clin. Nutr.* 100 (1) (2014) 123–151.
- [6] A. Fogel, A.T. Goh, L. Edelson, S. Sadananthan, S. Velan, N. Michael, M.T. Tint, M.V. Fortier, M.C. Chan, C.Y. Chong, K.H. Tan, F. Yap, L. Shek, M. Meaney, B. Broekman, Y.S. Lee, K. Godfrey, M.F.F. Chong, C.G. Forde, A description of the 'obesogenic' eating style that promotes greater adiposity in pre-school children; results from the GUSTO cohort, *Physiol. Behav.* 176 (2017) 107–116, <https://doi.org/10.1016/j.physbeh.2017.02.013>.
- [7] A. Fogel, A.T. Goh, L. Edelson, S. Sadananthan, S. Velan, N. Michael, M.T. Tint, M.V. Fortier, M.C. Chan, C.Y. Chong, K.H. Tan, F. Yap, L. Shek, M. Meaney, B. Broekman, Y.S. Lee, K. Godfrey, M.F.F. Chong, C.G. Forde, Faster eating rates are associated with higher ad libitum energy intakes, higher BMI and greater adiposity among 4.5-year-old children; results from the GUSTO cohort, *Br. J. Nutr.* 117 (7) (2017) 1042–1051, <https://doi.org/10.1017/S0007114517000848>.
- [8] A. Fogel, L.R. Fries, K. McCrickerd, A.T. Goh, M.J. Chan, P.L. Quah, J.Y. Toh, Y.S. Chong, K.H. Tan, F. Yap, L.P. Shek, M.J. Meaney, B.F.P. Broekman, Y.S. Lee, K.M. Godfrey, M.F.F. Chong, C.G. Forde, Oral processing behaviours that promote children's energy intake are associated with parent-reported appetitive traits: results from the GUSTO cohort, *Appetite* 126 (2018) 8–15, <https://doi.org/10.1016/j.appet.2018.03.011>.
- [9] A. Fogel, L.R. Fries, K. McCrickerd, A.T. Goh, M.J. Chan, P.L. Quah, J.Y. Toh, Y.S. Chong, K.H. Tan, F. Yap, L.P. Shek, M.J. Meaney, B.F.P. Broekman, Y.S. Lee, K.M. Godfrey, M.F.F. Chong, C.G. Forde, Eating in the absence of hunger: stability over time and associations with eating behaviours and body composition in children, *Physiol. Behav.* 192 (2018) 82–89, <https://doi.org/10.1016/j.physbeh.2018.03.033>.
- [10] A. Fogel, L.R. Fries, K. McCrickerd, A.T. Goh, M.J. Chan, J.Y. Toh, Y.S. Chong, K.H. Tan, F. Yap, L.P. Shek, M.J. Meaney, B.F.P. Broekman, Y.S. Lee, K.M. Godfrey, M.F.F. Chong, C.G. Forde, Prospective associations between parental feeding practices and children's oral processing behaviours, *Matern. Child Nutr.* 15 (1) (2019), e12635.
- [11] C.G. Forde, A. Fogel, K. McCrickerd, Children's eating behaviors and energy intake: Overlapping influences and opportunities for intervention, *Nurturing a Healthy Generation of Children: Research Gaps and Opportunities*, vol. 91, Karger Publishers 2019, pp. 55–67, <https://doi.org/10.1159/000493695>.
- [12] A. Fogel, A.T. Goh, L. Edelson, S. Sadananthan, S. Velan, N. Michael, M.T. Tint, M.V. Fortier, M.C. Chan, C.Y. Chong, K.H. Tan, F. Yap, L. Shek, M. Meaney, B. Broekman, Y.S. Lee, K. Godfrey, M.F.F. Chong, C.G. Forde, Associations between inhibitory control, eating behaviours and adiposity in 6-year-old children, *Int. J. Obes.* (2019), <https://doi.org/10.1038/s41366-019-0343-y>.
- [13] K.D. Hall, A. Ayuketah, S. Bernstein, R. Brychta, H. Cai, T. Cassimatis, K.Y. Chen, S.T. Chung, E. Costa, A. Courville, V. Darcey, L.A. Fletcher, C.G. Forde, A.M. Gharib, J. Guo, R. Howard, P.V. Joseph, S. Megehee, R. Ouwerkerk, K. Raisinger, I. Rozga, M. Stagliano, M. Walter, P.J. Walter, M. Zhou, Ultra-processed diets cause excess calorie intake and weight gain: a one-month inpatient randomized controlled trial of ad libitum food intake, *Cell Metab.* 30 (2019) 67–77, <https://doi.org/10.1016/j.cmet.2019.05.008>.
- [14] A. Fogel, A.T. Goh, L. Edelson, S. Sadananthan, S. Velan, N. Michael, M.T. Tint, M.V. Fortier, M.C. Chan, C.Y. Chong, K.H. Tan, F. Yap, L. Shek, M. Meaney, B. Broekman, Y.S. Lee, K. Godfrey, M.F.F. Chong, C.G. Forde, Eating behaviours moderate the associations between risk factors in the first 1000 days and adiposity outcomes at 6 years of age, *Am. J. Clin. Nutr.* 111 (5) (2020) 997–1006, <https://doi.org/10.1093/ajcn/nqaa052> May 2020.
- [15] P.S. Teo, C.G. Forde, The impact of eating rate on energy intake, body composition and health, in: H.L. Meiselman (Ed.), *Handbook of Eating and Drinking*, Springer 2020, pp. 715–740, <https://doi.org/10.1007/978-3-319-75388>.
- [16] P.S. Teo, C. Whitton, R.M. Van Dam, L.W.L. Tan, C.G. Forde, Associations between self-reported eating rate, energy intake and cardiovascular risk factors in a multi-ethnic Asian population, *Nutrients* 12 (4) (2020) 1080, <https://doi.org/10.3390/nu12041080>.
- [17] P.S. Teo, R.M. Van Dam, C.G. Forde, The combined impact faster eating rate and higher energy intake rate in promoting greater energy intake, BMI and adiposity in a population based cohort, *Nutrients* 12 (11) (2020) 3264, <https://doi.org/10.3390/nu12113264>.
- [18] P.S. Teo, C. Whitton, R.M. Van Dam, L.W. Tan, L. and Forde C.G., Consuming foods with a higher energy intake rate is associated with greater energy intake, adiposity and cardiovascular risk factors, *J. Nutr.* 151 (2) (2021) 370–378, <https://doi.org/10.1093/jn/nxaa344>.
- [19] P.S. Teo, R. Tso, R.M. Van Dam, C.G. Forde, Taste of modern diets: the impact of food processing on nutrient sensing and dietary energy intake, *J. Nutr.* (2021), <https://doi.org/10.1093/jn/nxab318>.
- [20] M.J. Gibney, C.G. Forde, Nutrition research challenges for processed food and health, *Nat. Food* 3 (2022) 104–109, <https://doi.org/10.1038/s43016-021-00457-9>.
- [21] P.S. Teo, V.T.W. Tan, M.J. Choy, R. Janani, A. Lim, A.T. Goh, K. McCrickerd, C.G. Forde, Texture-based differences in eating rate moderate energy intake for unprocessed and ultra-processed meals, *Am. J. Clin. Nutr.* 116 (1) (2022) 244–254, <https://doi.org/10.1093/ajcn/nqac068>; July 2022.
- [22] C.G. Forde, E. Decker, The importance of food processing and eating behavior in promoting healthy and sustainable diets, *Annu. Rev. Nutr.* 2022 (42) (2022) 377–399, <https://doi.org/10.1146/annurev-nutr-062220030123>.
- [23] C.G. Forde, D. Bolhuis, Interrelations between food form, texture and matrix on energy intake and metabolic responses, *Curr. Nutr. Rep.* (2022), (Accepted – In Press) <http://dx.doi.org/10.1007/s13668-022-00413-4>.
- [24] M.S. Wee, A.T. Goh, M. Stieger, C.G. Forde, Correlation of mechanical properties from the textural profile analysis (TPA) with eating Behaviours and macronutrient composition for a wide range of solid foods, *Food Funct.* 9 (2018) 5301–5312, <https://doi.org/10.1039/C8FO00791H>.
- [25] M.S. Wee, V. Tan, D.E. Loud, C.G. Forde, Physical and sensory characterisation of noodles with added native and denatured pea-protein isolate, *Food Chem.* 294 (October 2019) (2019) 152–159, <https://doi.org/10.1016/j.foodchem.2019.05.042>.
- [26] D. Bolhuis, C.G. Forde, Application of food texture to moderate oral processing behaviours and energy intake, *Trends Food Sci. Technol.* 106 (2020) 445–456, <https://doi.org/10.1016/j.tifs.2020.10.021>.
- [27] A.T. Goh, M. Choy, X.H. Chua, S. Ponnalagu, C.M. Khoo, C. Whitton, R.M. van Dam, C.G. Forde, Increased Oral processing and a slower eating rate enhances glycaemic, insulin and satiety responses to a mixed meal tolerance test, *Eur. J. Nutr.* 2021 (60) (2021) 2719–2733, <https://doi.org/10.1007/s00394-020-02466-z>.
- [28] A.T. Goh, G. Chatonidi, M. Choy, M. Stieger, C.G. Forde, Impact of individual differences in eating rate on oral processing, and post-meal glucose and satiety responses, *Physiol. Behav.* 238 (2021) 113495, <https://doi.org/10.1016/j.physbeh.2021.113495> 1 September 2021.
- [29] M. Choy, G. Chatonidi, A.T. Goh, S. Ponnalagu, M. Stieger, C.G. Forde, Impact of food texture modifications on Oral processing behaviour, bolus properties and postprandial glucose responses, *Curr. Res. Food Sci.* 4 (2021) (2021) 891–899, <https://doi.org/10.1016/j.crf.2021.11.018>.
- [30] A.T. Goh, Y. Jiali, X.H. Chua, C. Whitton, R.M. van Dam, C.G. Forde, Associations between oral processing, saliva, and bolus properties on daily glucose excursions amongst people at risk of type-2 diabetes, *Food Funct.* (2023), <https://doi.org/10.1039/d2fo03060h>.
- [31] C.G. Forde, M. Stieger, Metabolic impact of oral processing, in: B. Wolf, S. Bakalis, J. Chen (Eds.), *Oral Processing and Consumer Perception*, Royal Society of Chemistry 2022, pp. 137–186, Chpt. 6, <http://dx.doi.org/10.1039/9781839160622-00137>.
- [32] Y. Chen, M. Stieger, E. Capuano, C.G. Forde, S. van der Haar, M. Ummels, H. van den Bosch, R. de Wijk, Influence of oral processing behaviour and bolus properties of brown rice and chickpeas on in vitro starch digestion and postprandial glycaemic response, *Eur. J. Nutr.* (2021), <https://doi.org/10.1007/s00394-022-02935-7>.
- [33] C. Tournier, C.G. Forde, Food oral processing and eating behavior from infancy to childhood: evidence on the role of food texture in the development of healthy eating behavior, *Crit. Rev. Food Sci. Technol.* (2023), <https://doi.org/10.1080/10408398.2023.2214227>.
- [34] S. Nicklaus, L. Demonteil, C. Tournier, Modifying the texture of foods for infants and young children, *Modifying Food Texture*, Woodhead Publishing 2015, pp. 187–222.
- [35] B.J. Le Révérend, L.R. Edelson, C. Loret, Anatomical, functional, physiological and behavioural aspects of the development of mastication in early childhood, *Br. J. Nutr.* 111 (3) (2014) 403–414.
- [36] V. Tan, A. Lim, K. McCrickerd, C.G. Forde, Sensory profiles and Mothers' expectations and beliefs about age appropriate snacks for infants and toddlers in Singapore, *Food Qual. Prefer.* 97 (2022), 104474, <https://doi.org/10.1016/j.foodqual.2021.104474>.
- [37] C.G. Forde, N. van Kuijk, T. Thaler, C. de Graaf, N. Martin, Oral processing characteristics of solid meal components and relations with food composition, sensory attributes and expected satiation, *Appetite* 60 (2013) 208–219.
- [38] C.G. Forde, N. van Kuijk, T. Thaler, C. de Graaf, N. Martin, Texture and savoury taste influences on food intake for a realistic hot lunch-time meal, *Appetite* 60 (2013) 180–186.
- [39] D.P. Bolhuis, C.G. Forde, Y. Cheng, H. Xu, N. Martin, C. DeGraaf, Slow food: sustained impact of harder foods on the reduction in energy intake over the course of the day, *PLoS One* 9 (4) (2014), e93370, <https://doi.org/10.1371/journal.pone.0093370>.
- [40] K. McCrickerd, C.M.H. Lim, C. Leong, E. Chia-Ming, C.G. Forde, Texture-based differences in eating rate can reduce the influence of portion size and energy density on meal intake, *J. Nutr.* 147 (6) (2017) 1208–1217, <https://doi.org/10.3945/jn.116.244251>.
- [41] R. Janani, V.K.W. Tan, M.J.Y. Choy, A. Lim, A.T. Goh, P.S. Teo, M. Stieger, C.G. Forde, Independent and combined impact of texture manipulation on oral processing among faster and slower eaters, *Food Funct.* 13 (2022) 9340–9354, <https://doi.org/10.1039/D2FO00485B>.
- [42] L.A.J. Heuven, K. de Graaf, C.G. Forde, D.P. Bolhuis, Al dente or well done? How the eating rate of a pasta dish is modified by the eating rate of its components, *Food Qual. Prefer.* 108 (2023) 104883, <https://doi.org/10.1016/j.foodqual.2023.104883> May 2023.



**Prof. Ciarán G. Forde**, Chairholder: Sensory Science and Eating Behaviour Chair group., Division of Human Nutrition and Health, Wageningen University and Research, the Netherlands.

Professor Ciarán Forde is the Chair in Sensory Science and Eating Behaviour at the Division of Human Nutrition and Health, at Wageningen University and Research in the Netherlands. He leads research on how the sensory properties of foods influence eating behaviours, energy intake and metabolism across the life-span. Prof. Forde has published and presented widely, on topics in sensory, nutrition and metabolism. Prof. Forde is an Executive Editor for the journal *Appetite* and is Section Editor for the *European Journal of Nutrition*, and Editorial board member for *Nutrition Bulletin*, *Journal of Future Food* and *Journal of Texture Studies*. Before joining Wageningen

University, Prof. Forde has spent the previous 20 years in academic, public and private sector research roles in the UK (GSK), Australia (CSIRO) and Switzerland (Nestlé Research) and Singapore (National University of Singapore/A\*STAR). He received his BSc (Hons) in Food Chemistry and a PhD in Sensory Science from the Department of Nutrition in University College Cork in Ireland.

**Email:** [ciaran.forde@wur.nl](mailto:ciaran.forde@wur.nl)

**WWW:** <https://www.wur.nl/en/research-results/chair-groups/agrotechnology-and-food-sciences/human-nutrition-and-health/sensory-science-and-eating-behaviour.htm>

**LinkedIn:** <https://www.linkedin.com/in/ciaran-forde-0766995>

**Research Gate:** <https://www.researchgate.net/profile/Ciaran-Forde>

**Twitter:** @fordeyce